Increased resolution in HighResMIP/PRIMAVERA models: biases and future plans
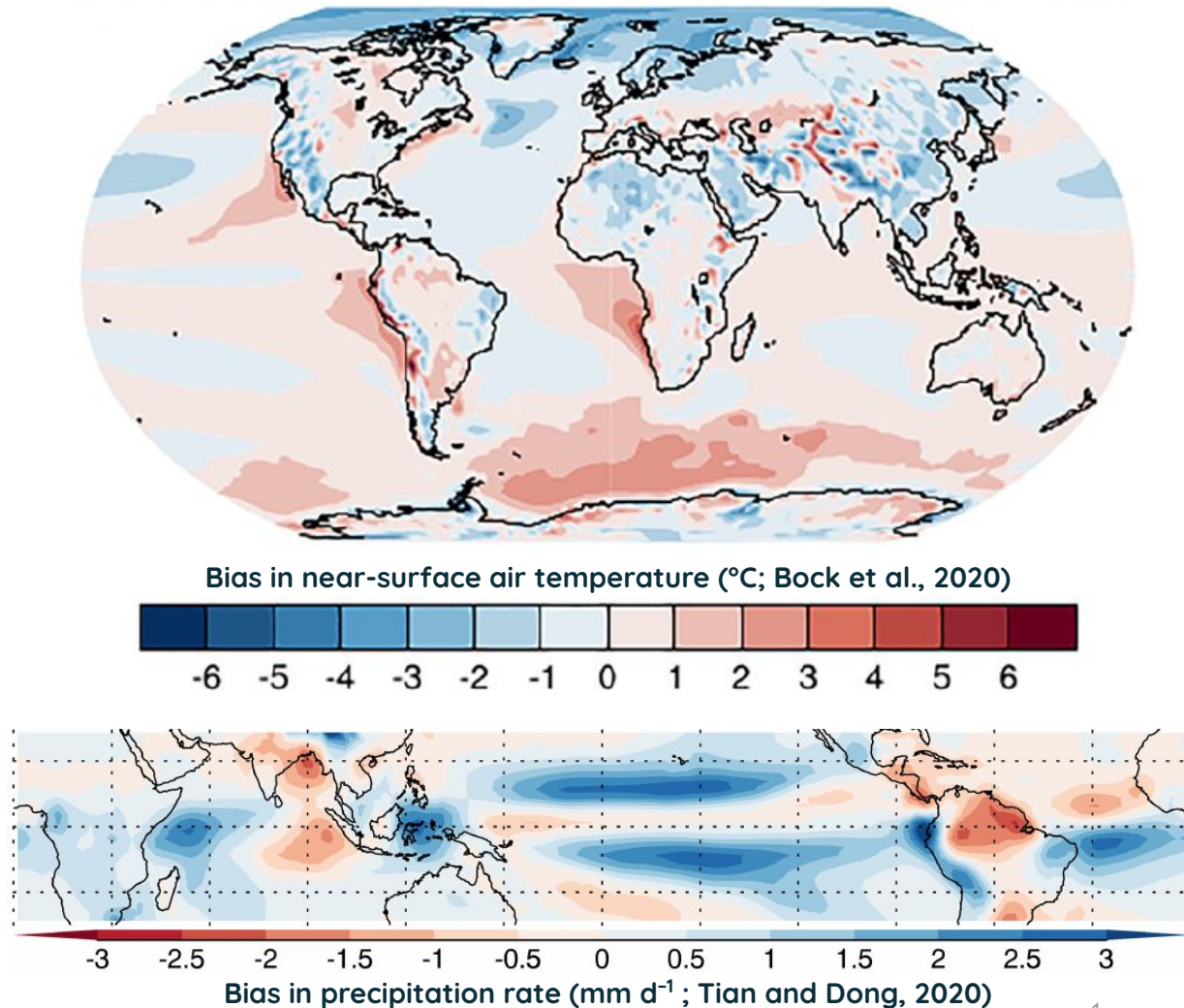
Eduardo Moreno-Chamarro

Louis-Philippe Caron, Pablo Ortega, Saskia Loosveldt Tomas, Javier Vegas-Regidor, Oliver Gutjahr, Marie-Pierre Moine, Dian Putrasahan, Christopher D. Roberts, Malcolm J. Roberts, Retish Senan, Laurent Terray, Etienne Tourigny, Pier Luigi Vidale

Biases in CMIP6 models

Examples of well-known biases persisting across model generations:

1. Upwelling regions
2. Double ITCZ
3. Southern Ocean
4. North Atlantic Ocean

Bias in near-surface air temperature (°C; Bock et al., 2020)

Bias in precipitation rate (mm d^{-1} ; Tian and Dong, 2020)

To what extent does increased resolution (alone) help reduce biases?

A subset of global models developed within the PRIMAVERA project
Historical simulations following the CMIP6 HighResMIP protocol
No additional (or minimal) tuning between resolutions

	CNRM-CM6-1		EC-Earth3P		ECMWF-IFS		HadGEM3-GC31			MPI-ESM-2	
Resolution name	LR	HR	LR	HR	LR	HR	LL	HM	HH	HR	XR
Atmosphere nominal resolution (km)	207	75	107	54	80	40	217	41	41	134	67
Ocean resolution (degrees; km)	1° (100)	0.25° (25)	1° (100)	0.25° (25)	1° (100)	0.25° (25)	1° (100)	0.25° (25)	0.08° (8)	0.4° (50)	0.4° (50)
Reference	Voldoire et al. (2019)		Haarsma et al. (2020)		Roberts et al. (2018)		Roberts et al. (2019)			Gutjahr et al. (2019)	

(Moreno-Chamarro et al., in review; GMD)

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Some SAT biases are reduced at higher resolution

a. ERA-Interim SAT (°C)
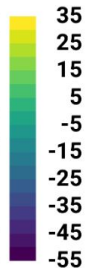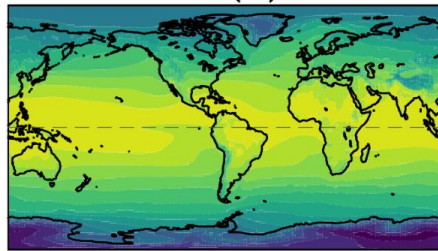
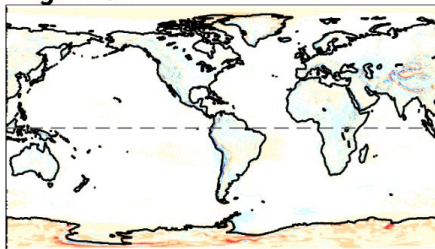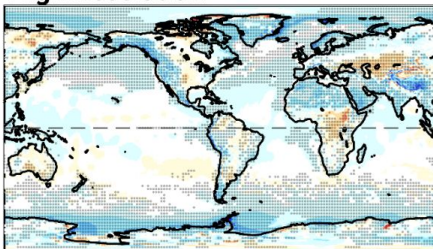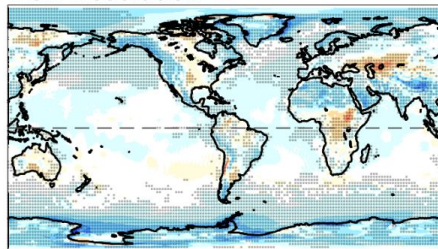Well-known biases also in the ensemble mean of coupled models at LR

At HR, slight bias reduction in upwelling regions and warming of the subpolar North Atlantic
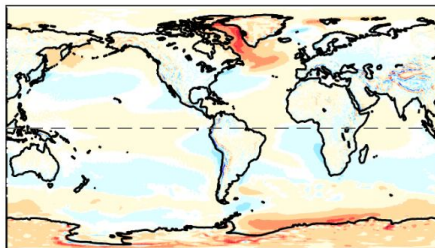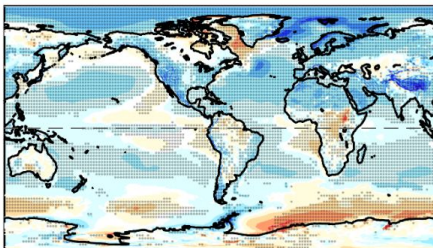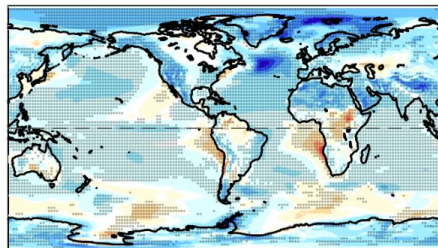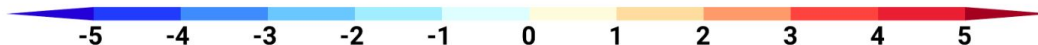
b. Low Resolution | High Resolution | High−Low
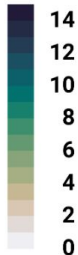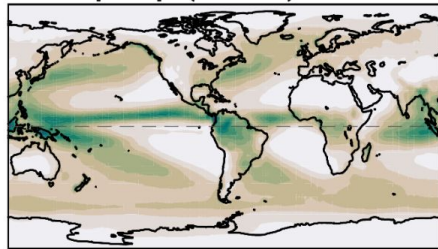
Atmosphere-only

Ensemble mean SAT biases (°C)

Coupled

Persistent large biases in precipitation at HR

a. GPCP precip. (mm d^{-1})

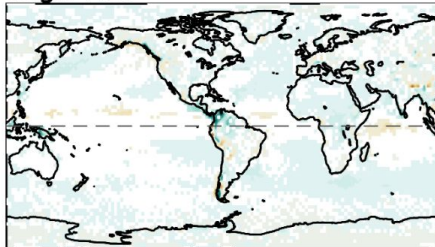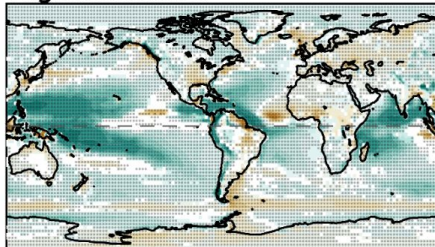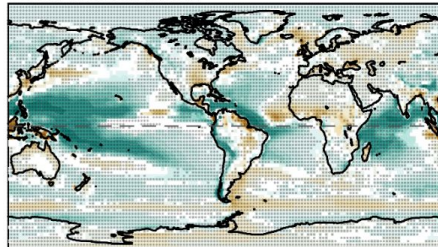Double ITCZ reduced in HR coupled models

Insignificant bias reduction in the atmosphere-only models (forced by observed SSTs)

b. Low Resolution   High Resolution   High−Low

Atmosphere-only
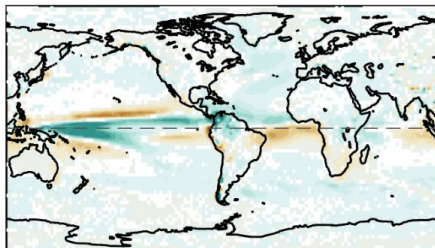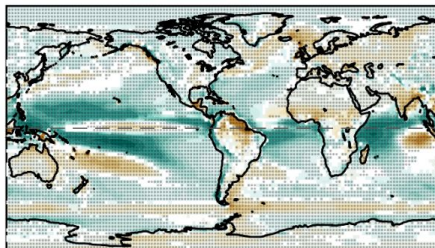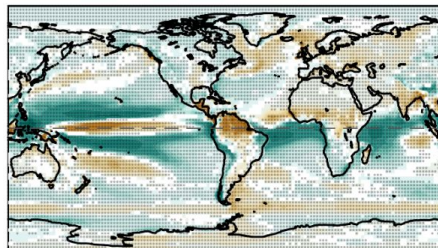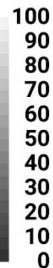
Ensemble mean precip. biases (mm d^{-1})

Coupled

-3.5 -1.5 -1 -0.5 0 0.5 1 1.5 3.5

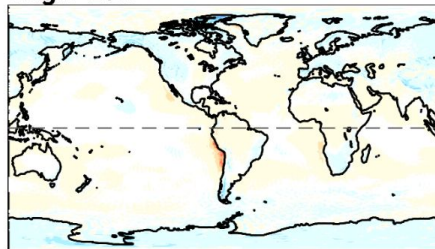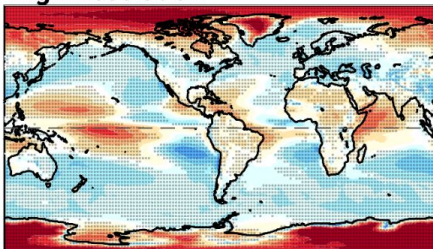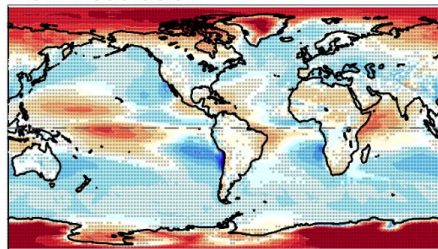# Biases in cloud cover insensitive to resolution or coupling

a. ESA CCI-CLOUD cover (%)
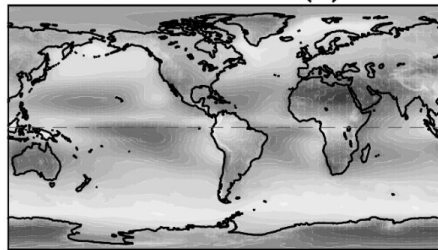
Slight bias reduction in the upwelling regions but bias increase in the equatorial Pacific

b.

Ensemble mean cloud cover biases (%)
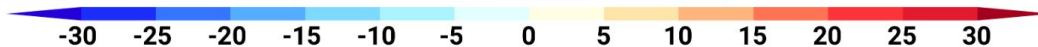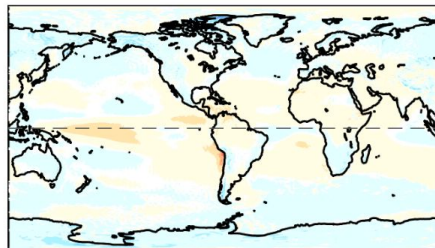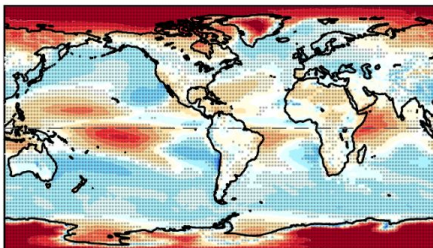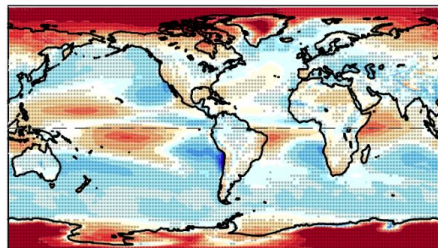
Large disparity across ensemble members

E.g.: biases in SAT (°C) in the individual coupled models
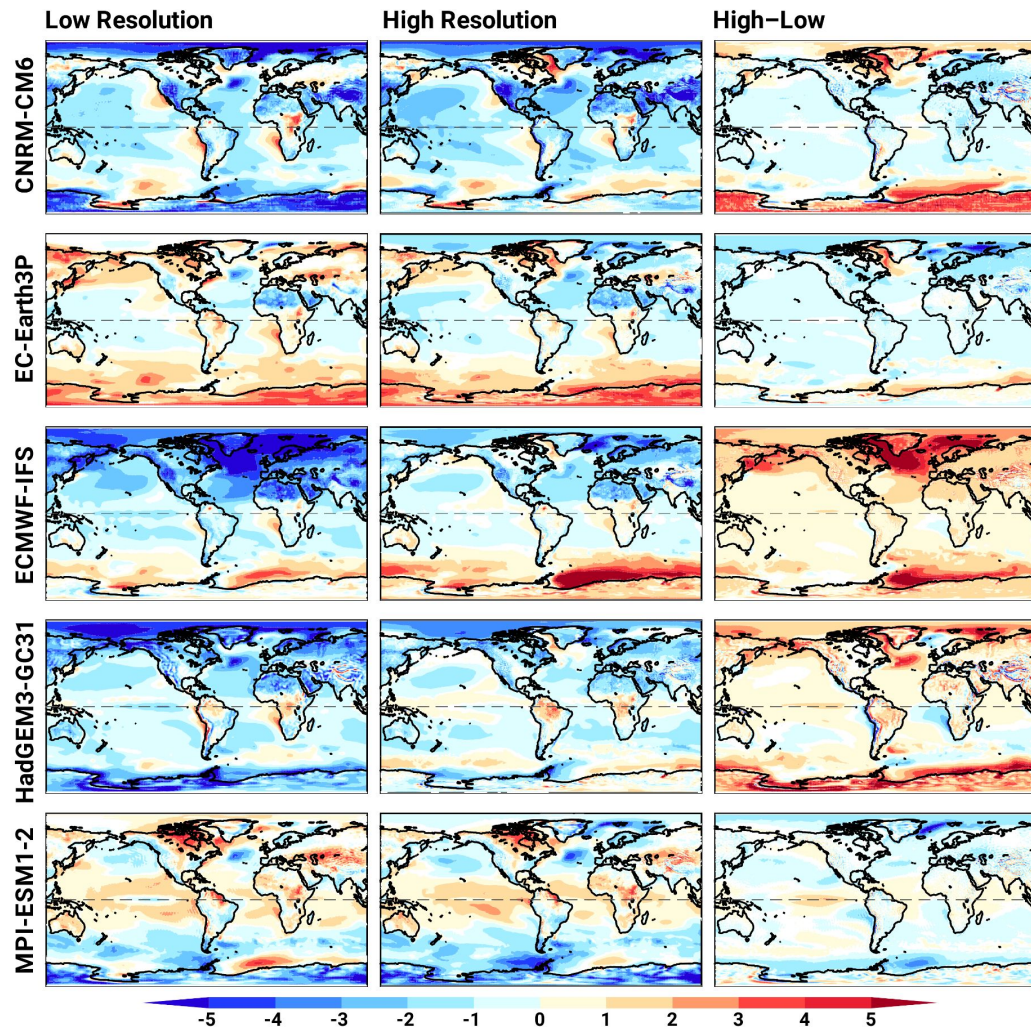
HadGEM3-GC31: one of the best improving models with increased resolution

Clear reductions in three biases:
1. upwelling regions
2. double ITCZ
3. North Atlantic

Similar bias reductions in an eddy-present (~25 km; HM) and eddy-rich (~8 km; HH) ocean models coupled to a 50-km atmosphere model
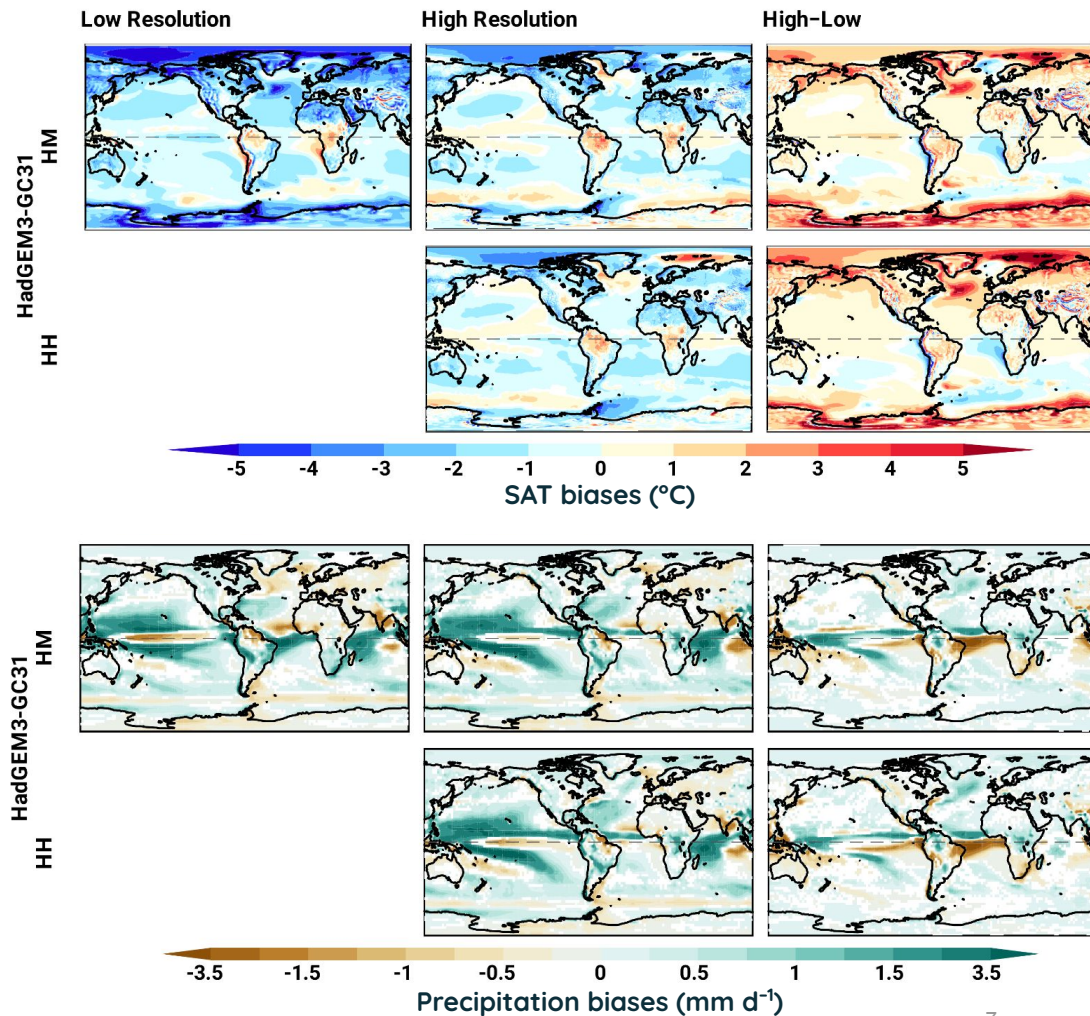
A sharper Gulf Stream that shifts northward over time only in the HadGEM3-GC31 eddy-rich model

Change in meridional gradient in sea-surface height (10^{-6} mm^{-1})
1993–2018 AVISO satellite climatology (dashed line)

(Moreno-Chamarro et al., 2021; ERL)
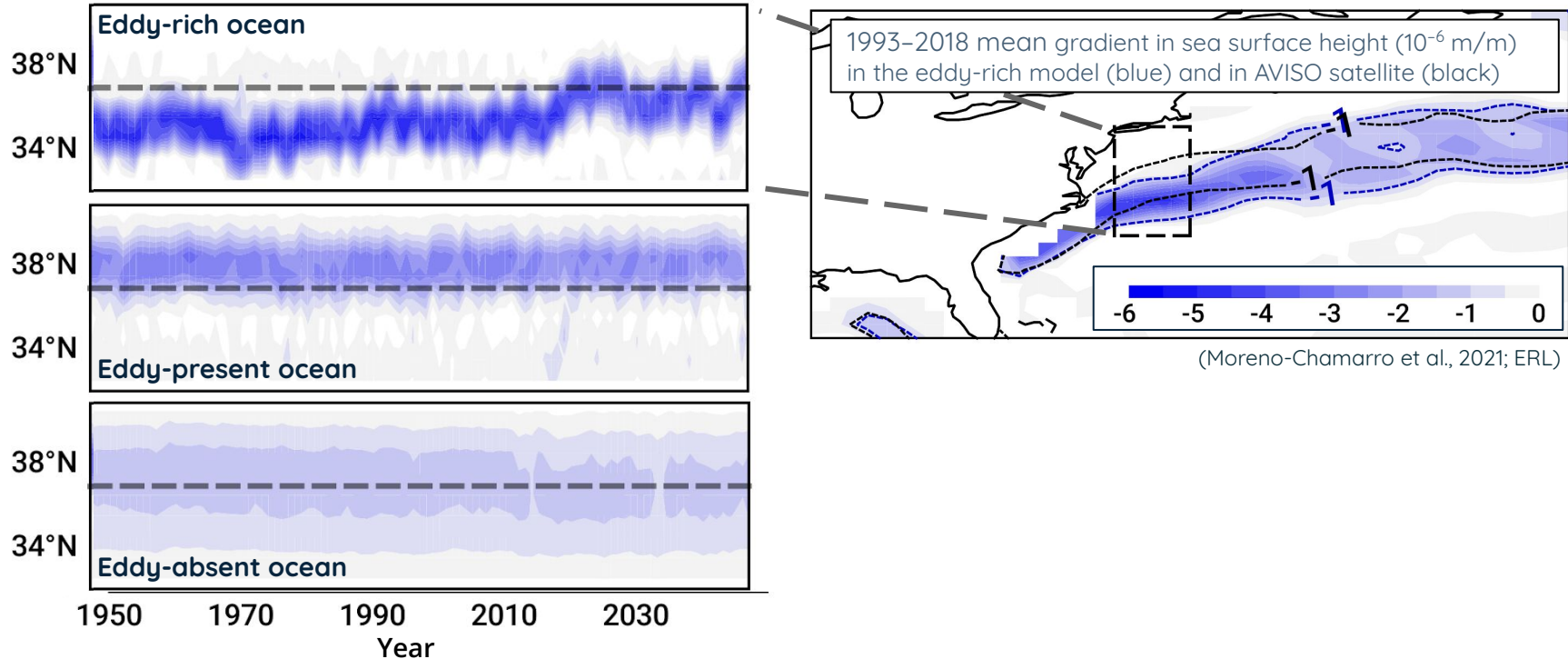
Future northward Gulf Stream shift together with ocean surface warming, storm tracks intensification, and increased winter precipitation over Europe

2030–2050 vs. 1960–1980 change in

Sea-surface temperature (°C)
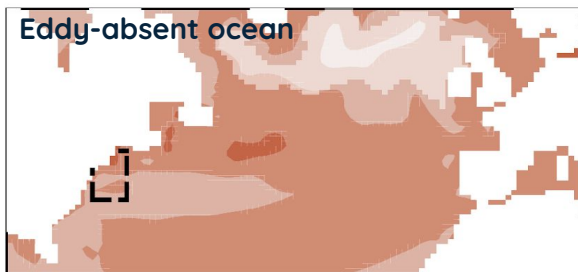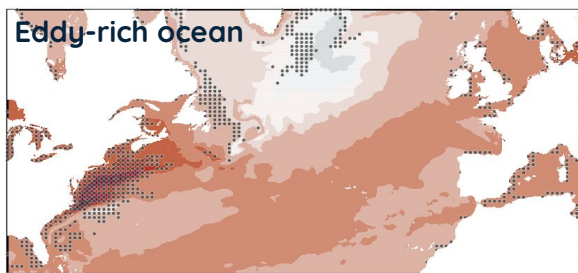
DJF max. eady growth rate (d⁻¹)
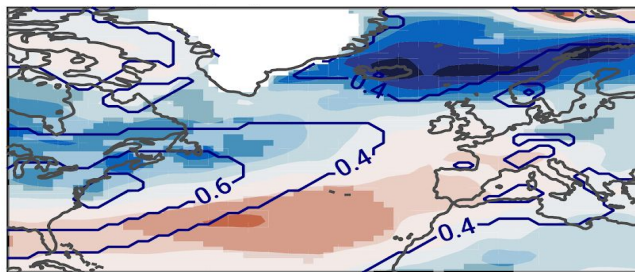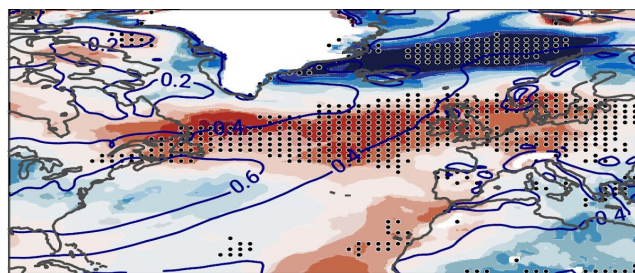
DJF precipitation (mm d⁻¹)
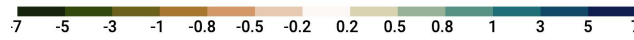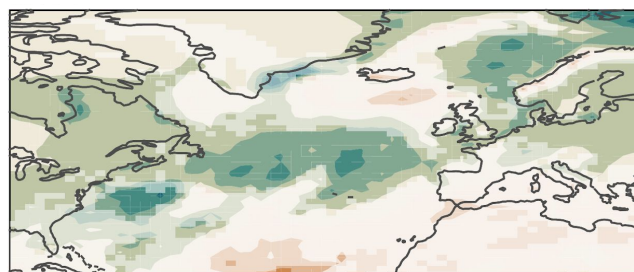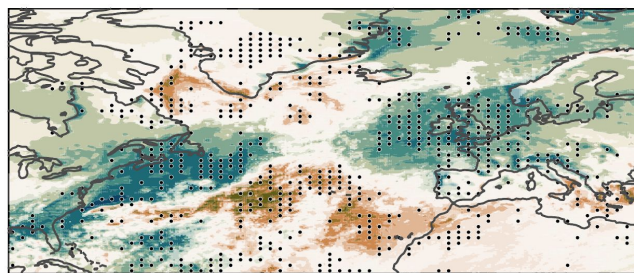
(Moreno-Chamarro et al., 2021; ERL)
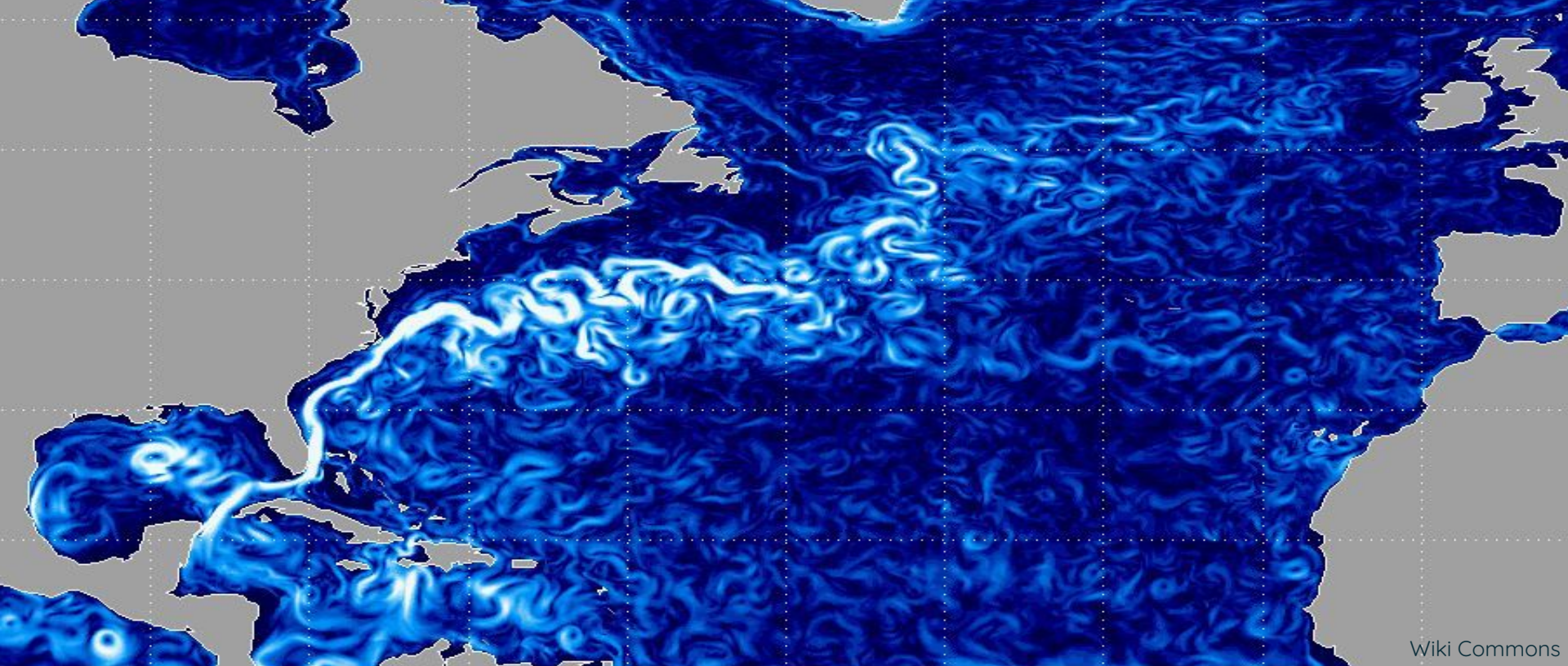
Wiki Commons

STREAM: STirring the ocean: the Role of ocean Eddies in the north Atlantic circulation, Mid-latitude climate prediction, and impacts

STREAM project: objectives and models

Quantify the impact of ocean mesoscale eddies on both present-day and future **North Atlantic ocean circulation**

Constrain how eddies shape the influence of the North Atlantic on the **European climate and future evolution**

Evaluate the impact of ocean eddies on the **near-term predictive skill** over Europe, with a main focus on surface air temperature and precipitation

EC-Earth-VHR   (15-km atmosphere and ocean)
EC-Earth-HR   (40-km atmosphere, and 25-km ocean)
In collaboration with Met Office, Max Planck Institute for Meteorology, and
Texas A&M University/International Laboratory for High-Resolution Earth System Prediction

High-resolution climate modeling researcher (R2)

Job Reference	Position	Closing Date
339_21_ES_CP_R2	High-resolution climate modeling researcher (R2)	Friday, 15 October, 2021

Reference: 339_21_ES_CP_R2
Job title: High-resolution climate modeling researcher (R2)

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The Barcelona Supercomputing Center - Centro Nacional de Supercomputación (BSC-CNS) is the leading supercomputing center in Spain. It houses MareNostrum, one of the most powerful supercomputers in Europe, and is a hosting member of the PRACE European distributed supercomputing infrastructure. The mission of BSC is to research, develop and manage information technologies in order to facilitate scientific progress. BSC combines HPC service provision and R&D into both computer and computational science (life, earth and engineering sciences) under one roof, and currently has over 700 staff from 49 countries.

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SUMMARY

1. **Alone, increased resolution from ~100 km to 25–50 km does not contribute to reducing biases substantially**
    - It depends on the model/resolution
    - Further model development, tuning, or even finer resolutions might be needed

2. **Differences in the Gulf Stream position, strength, and future change between non-eddy and eddy-rich models**
    - It can lead to a different future response to GHG increase

3. **New project, STREAM, to explore ocean mesoscale in the North Atlantic and impacts on climate and predictability**